J. Synchrotron Rad. (1998). 5, 1195–1198

Present Status and Performance of SPring-8 Front Ends

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(*Received 19 November 1997; accepted 2 February 1998*)

SPring-8 front ends have a novel structure which makes it easy to rearrange them and exchange the components. The structure has a common support for all the components except X-ray beam-position monitors and lead collimators. The alignment of the common support as well as the components was carried out with an accuracy of 0.25 mm in the vertical and horizontal directions. Replaceable pumping systems have also been placed on the common support and have achieved a vacuum of 2×10^{-8} Pa at the upstream part of the front ends without synchrotron radiation. During the commissioning with synchrotron radiation, the pumping systems displayed good pumping-down characteristics. Commissioning has been successfully performed for four standard in-vacuum X-ray undulators and three bending-magnet-beamline front ends up to July 1997. Measurements of temperature rise show that absorber, pre-slits and *XY* slits can handle the anticipated maximum heat load at a ring current of 100 mA.

Keywords: front ends; common supports; pumping systems; alignment; beamline development.

1. Introduction

A standard in-vacuum X-ray undulator installed in a SPring-8 straight section produces powerful synchrotron radiation with a power density of about 500 kW mrad^{-2} and a total power of about 12 kW. In the present circumstances, stable handling of such a large emitted power and accurate position monitoring of the very narrow synchrotron radiation beam are major challenges in the field of front-end engineering. Efforts to develop the high-heat-load components and X-ray beam-position monitors (XBPM) should continue after the front-end construction is completed. Regarding the structure of the front ends, therefore, it is essential to be able to rearrange and replace the front-end components as easily as possible for upgrading them according to advances in engineering.

Conventional front-end components have a combined structure with a mounting support and a pumping system, and have been successfully installed at beamline front ends in synchrotron radiation facilities around the world. The conventional front ends can be assembled in a simple way; however, once construction has been completed, it is difficult to rearrange the front-end components.

Keeping these considerations in mind, we have adopted a novel structure for the SPring-8 front ends which separates the component bodies and mounting support. The XBPMs, however, are mounted on individual supports with low thermal expansion properties. Lead collimators are also supported separately since they are very heavy.

In this paper we present details of the structure and the performances of the novel SPring-8 front ends.

2. Layout and structure of SPring-8 front ends

The conceptual design of the front end is given in a previous paper (Sakurai *et al.*, 1995). The layout of the standard in-vacuum X-ray undulator beamline front end is shown in Fig. 1. The fixed mask confines the synchrotron radiation and prevents it from striking the uncooled parts of the front end. The absorber intercepts the synchrotron radiation to protect the downstream components, particularly the tungsten beam shutter. The synchrotron radiation is first defined by the pre-slit, which has four successively reduced apertures made of isotropic graphite brazed to water-cooled copper blocks. The final exit aperture of the pre-slit is 4 mm in diameter. Next, three graphite filters, each 0.1 mm thick, absorb the low-energy part of the defined synchrotron radiation so that the heat loads on the Be windows and optics are reduced. Finally, the size is reduced to a square of about 1 mm^2, which is large enough for the harmonic radiation to pass through. The front end accommodates two XBPMs. At the end of the front end, dual Be windows of thickness 0.25 mm are placed in the hard X-ray beamlines. Five vacuum pumping systems are placed on the common support, each of which consists of an ion pump, a Ti sublimation pump and a vacuum gauge.

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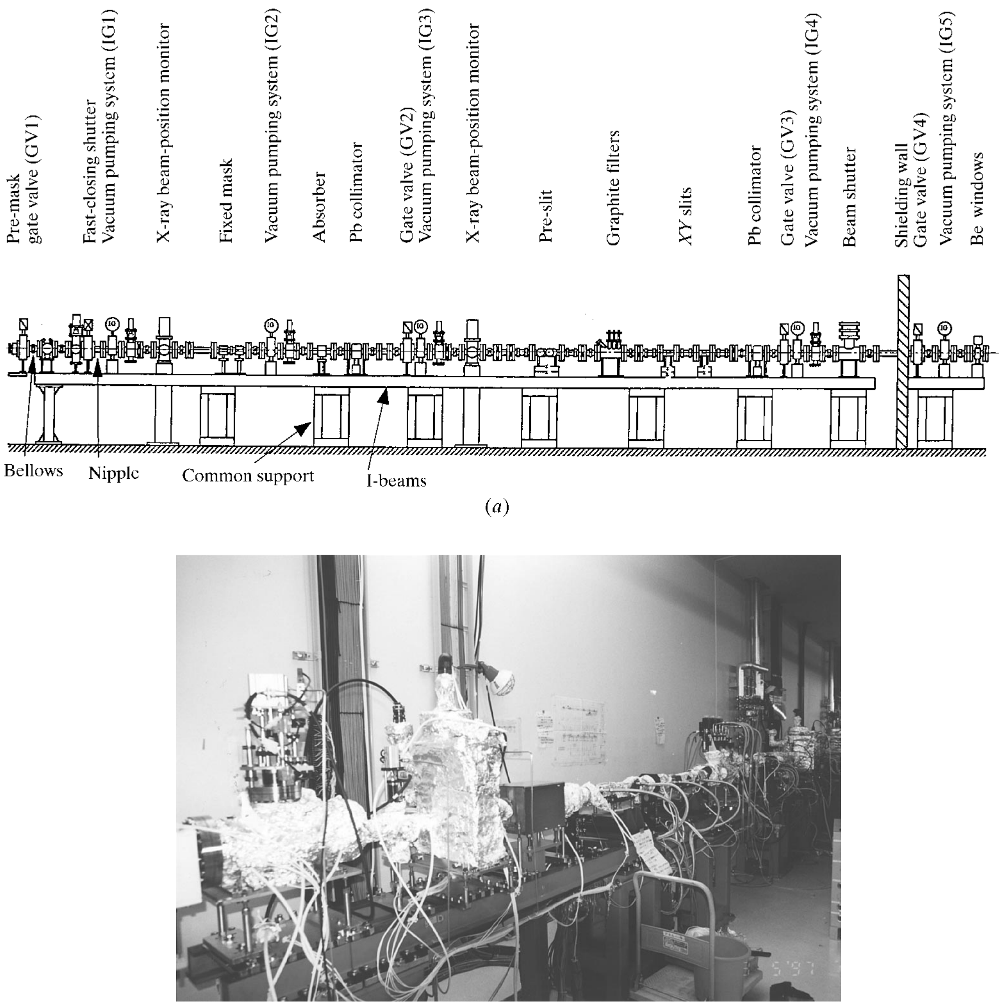
The synchrotron radiation passes through the body of the ion pumps. As shown in Fig. 2, the common support consists of two parallel I-beams and their base. One of the I-beams has a reference plane for the horizontal direction, and both have reference planes for the vertical direction. The front-end components to be mounted on the support also have reference planes. First, the reference planes on the common support are aligned to the beamline, and the flange centres of the components are also positioned precisely with respect to their reference planes. By putting the components on the common support, the flange centres are aligned to the beamline. The length of the I-beams is 2000 mm at maximum, and they are fixed to the bases.

Two types of XBPM support are used: one consists of a steel pipe filled with sand to reduce the temperature variation of the support body, and the other is made of carbon composite materials with negative thermal expansion coefficients to compensate the thermal expansion of the other part of the support.

3. Performance of the SPring-8 front ends

Precise alignment of the reference planes on the common support, as well as precise final alignment of the components, are essential to realize easily replaceable front ends. Fig. 3 shows the alignment errors of the horizontal and vertical reference planes on the common support, together with those of the flange centres of the installed front-end components. The errors were measured by using a high-precision telescope after these alignments had been performed. It is shown that the alignments of the reference planes as well as the flange centres of the components are carried out with an accuracy of 0.25 mm in both the vertical and the horizontal direction.

Five vacuum pumping systems are arranged along the beamline front end in the same way as the other components. The systems have achieved a vacuum of $\sim 10^{-8}$ Pa at the upstream part of the front ends without synchrotron radiation. The pumping-down characteristics of the standard in-vacuum X-ray undulator beamline front end (BL47XU) in the first commissioning period are shown in



(*a*)

(*b*)

Figure 1
(*a*) Schematic layout and (*b*) photograph of the standard in-vacuum undulator beamline front end.

Fig. 4. The pressures measured by ion gauges (IG1–5) are presented here as a function of the beam current (mA) multiplied by time (h), where the average current was approximately 16 mA. The positions of IG1–5 are shown in Fig. 1. The undulator was operated with $K = 2.3$, which produces a total power of about 2.5 kW and a power density of about 100 kW mrad^{-2}. The vacuum pumping systems show excellent pumping-down characteristics. Noticeable outgas was found in the fixed mask, absorber, graphite filters, pre-slit, *XY* slits and XBPMs when the synchrotron radiation was introduced, since they are directly irradiated by the synchrotron radiation. The vacuum pressure at IG3 is affected by the outgas from the graphite blocks used as fixed apertures in the pre-slit, while the pressure at IG1 is probably due to the outgas from the four tungsten blades of the XBPM. Assuming that the pressures are directly proportional to the storage-ring current, we estimate that it would take approximately 500 h for IG1–5 to reach the tentative goal pressure of 2×10^{-7} Pa at 100 mA operation.

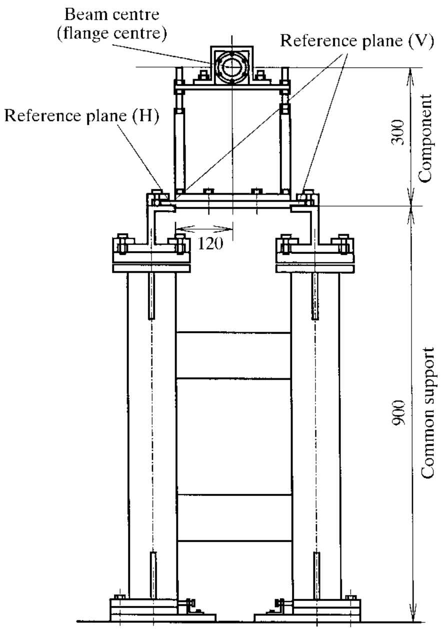


Figure 2
Structure of the common support and a component. Dimensions in mm.

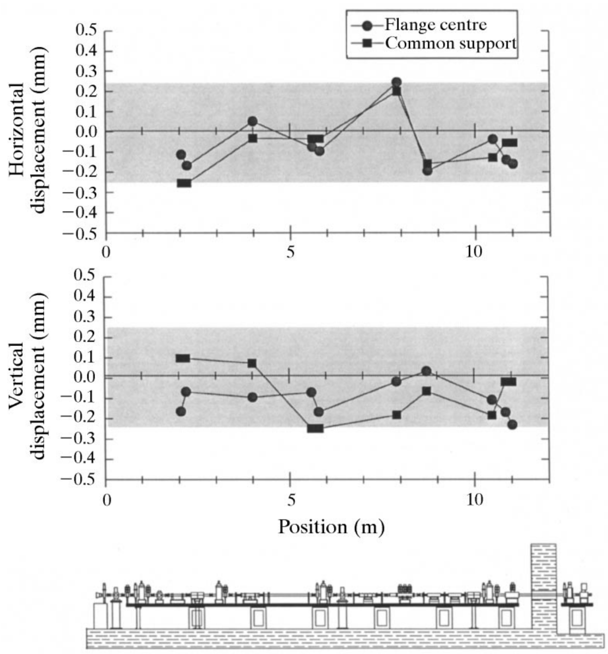


Figure 3
Alignment errors of the reference planes on the common support and the flange centres of the components.

The temperature rise was measured using a thermocouple for the absorber (Mochizuki *et al.*, 1998), pre-slit (Takahashi *et al.*, 1998) and *XY* slits (Oura *et al.*, 1998) in the X-ray undulator beamline at a minimum gap of 8 mm and a ring current of 18 mA. The temperature of the absorber rises by 6.5 K near the synchrotron-radiation-receiving surface and that of the *XY* slits increases by 10 K. The temperature of the Cu holder rises by 9 K in the pre-slits. Comparisons of these results and thermomechanical analyses show that these components can handle the heat load at 100 mA ring operation.

The tungsten-blade-type XBPM installed in the X-ray undulator beamline shows a spatial resolution of a few micrometres.

4. Conclusions

We have constructed the SPring-8 front ends incorporating a new idea, *i.e.* the separation of the common support from the vacuum pumping systems and components. The alignments of the common support as well as the flange centres of the components have been performed very well. The commissioning of the front ends has been successfully performed for four undulator beamlines and three

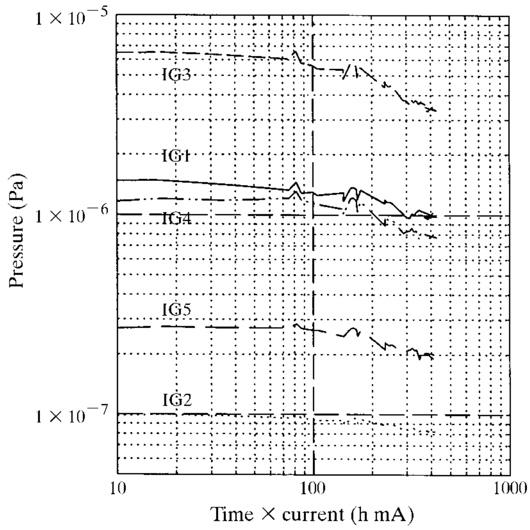


Figure 4
Pumping-down characteristics of the standard in-vacuum undulator beamline during the commissioning with synchrotron radiation.

bending-magnet beamlines. The pumping systems showed good pumping-down performance during the first commissioning period with synchrotron radiation. The undulator front ends have worked well under the minimum undulator gap of 8 mm at an 18 mA storage-ring current, which produces a total power of 2.5 kW and power density of 100 kW $mrad^{-2}$.

It is a pleasure to acknowledge many important discussions on the fixed mask, absorber and XBPM with Tunch Kuzay and Deming Shu at APS.

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